National Aeronautics and Space Administration

Review of Super-cooled Large Droplet Facility Capabilities

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Airframe Icing Technical Challenge

Airframe Icing Simulation and Engineering Tool Capability (FY25)

Develop and demonstrate 3-D capability to simulate and model airframe ice accretion and related aerodynamic performance degradation for current and future aircraft configurations in an expanded icing environment that includes freezing drizzle/rain

Goal: *Achieve acceptance of simulation tools for design and certification of swept wing configurations over an expanded range of icing conditions.*

Benefit: *Enable aircraft manufacturers to perform reliable icing assessments and build in effective icing mitigation approaches for current and future aircraft; development of technology that enables safe flight operations in an super-cooled large droplet environment*

Benefit Domain: *Aircraft and aircraft sub-system manufacturers and aviation system regulators*

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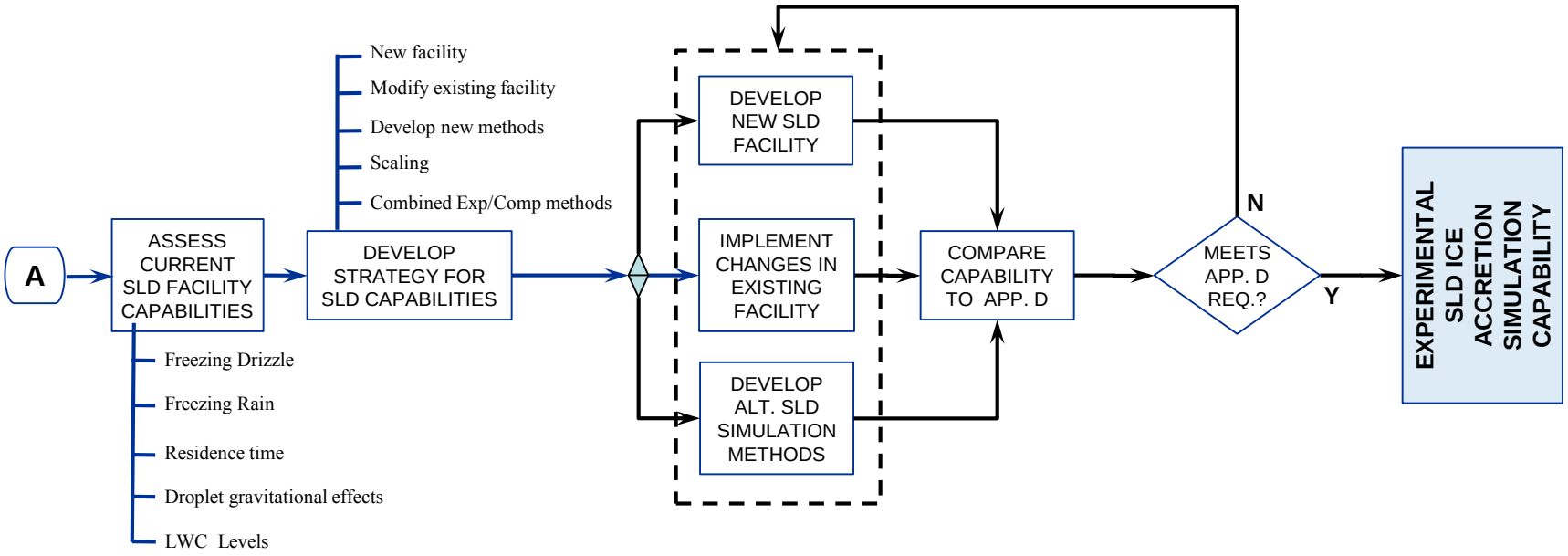
Experimental SLD Ice Accretion Simulation

Technology Development Roadmap



Experimental SLD Ice Accretion Simulation

Objective

Develop and demonstrate experimental simulation capability for SLD ice build-up on aircraft surfaces.

Research Tasks

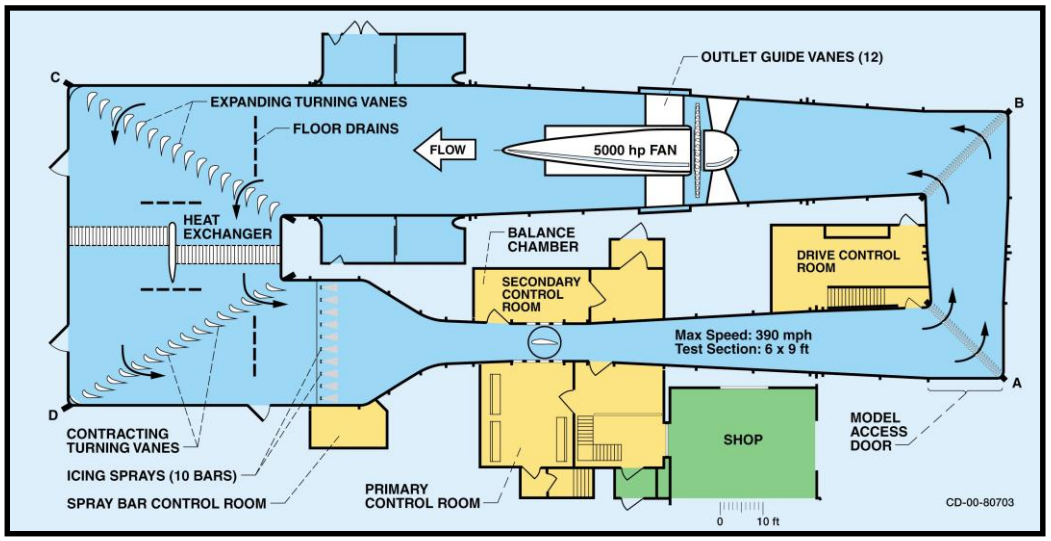
- Assessment of Current Known SLD Simulation Capabilities
  - Identify facilities with known or potential SLD capabilities
  - Identify characteristics required for SLD simulation
  - Compare facility capabilities to requirements
  - Identify gaps in capabilities
  - Recommend strategies for development of SLD experimental simulation capabilities

Super-cooled Large Droplet (SLD) Icing

- On 31 October 1994 a regional air transport crashed during a rapid descent following an uncommanded roll excursion, resulting in 68 fatalities. The uncommanded roll excursion occurred during the initial descent from a 32 minutes hold at 10,000 in intermittent icing conditions. The NTSB estimated that the icing conditions consisted of supercooled drops greater than 1,000 µm, with some as large as 2,000 µm, liquid water content varying between less that 0.1 g/m^3 to nearly 1.0 g/m^3, and a temperature of -3˚ C.

- NTSB Safety Recommendation A-96-54:
  - Revise the icing criteria published in 14 CFR, Parts 23 and 25, in light of both recent research into ice accretion under varying conditions of liquid water content, drop size distribution, and temperature, and recent developments in both the design and use of aircraft. Also, expand the Appendix C icing certification envelope to include freezing drizzle/freezing rain and mixed water/ice crystal conditions, as necessary.

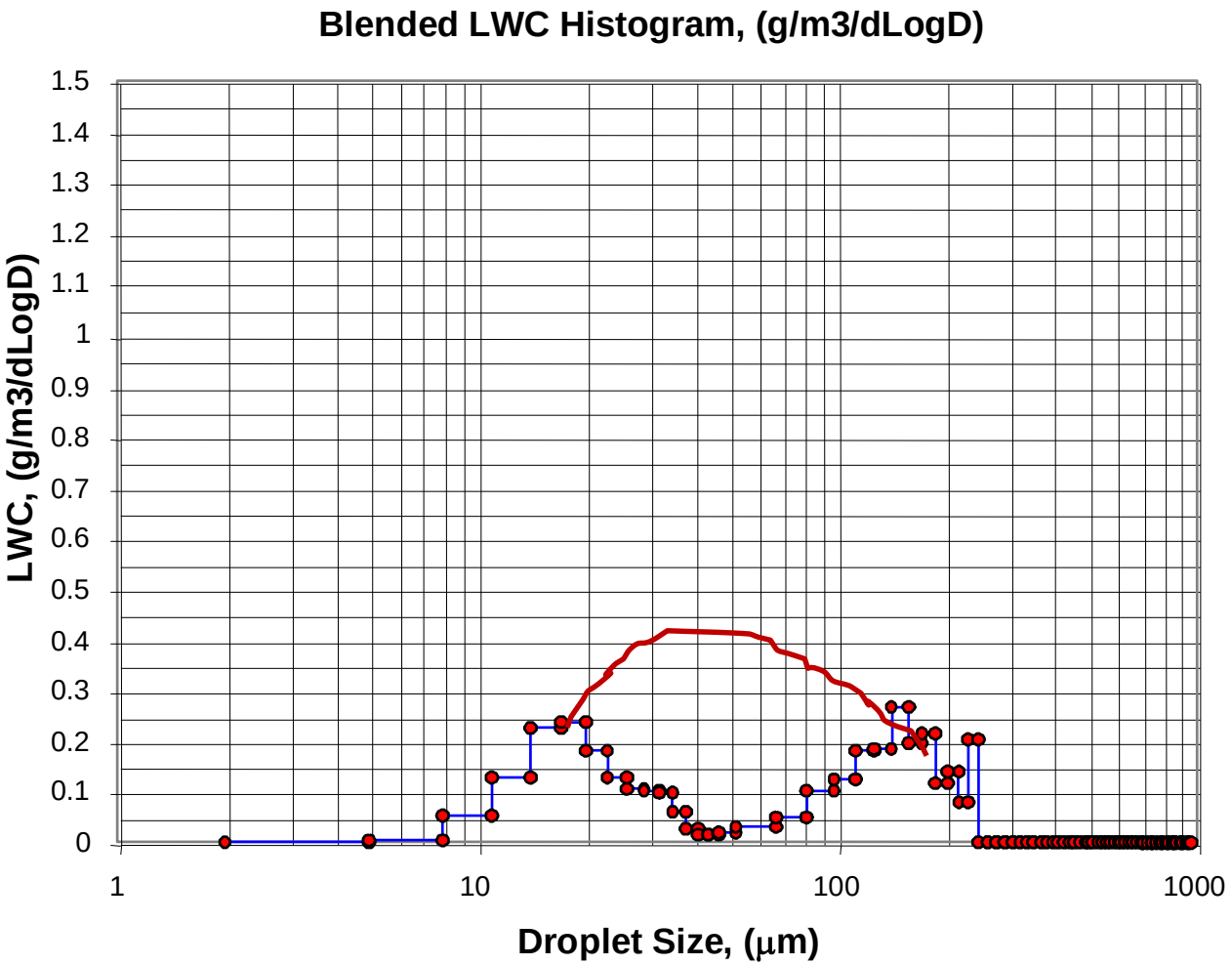
Icing Wind Tunnel Characteristics



Icing wind tunnel characteristics required for SLD simulation:

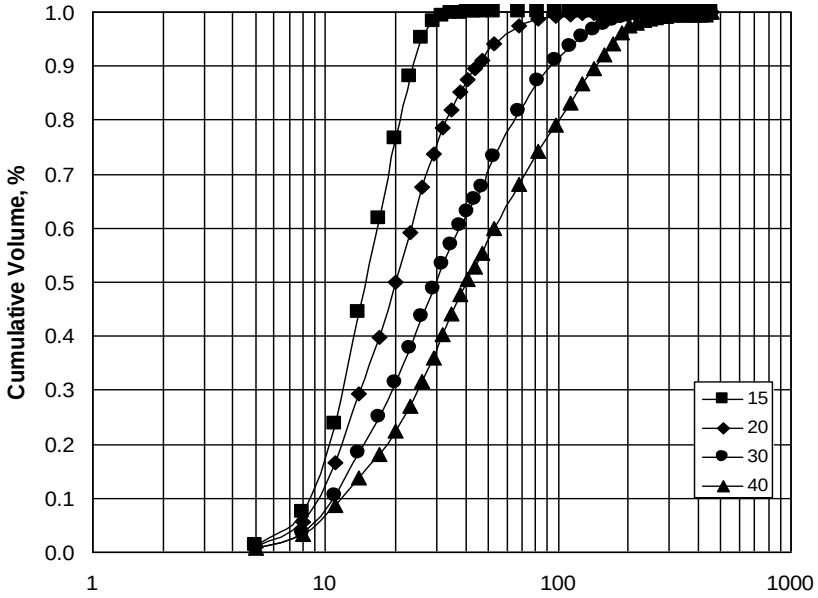
- Flight speeds at the test section
- Icing cloud conditions
  - ➢ Sub-freezing temperatures
    - ✓ 0° C to -25° C
  - ➢ Super-cooled water droplets
    - ✓ Droplet diameters ranging from 5 – 1200 microns
    - ✓ Droplet diameter distributions similar to those in the environment
    - ✓ Droplet temperatures at ambient in the test section
  - ➢ Cloud water content levels
    - ✓ Approximately 0.1 – 0.5 g/m^3
  - ➢ Cloud Uniformity

SLD Icing Characteristics

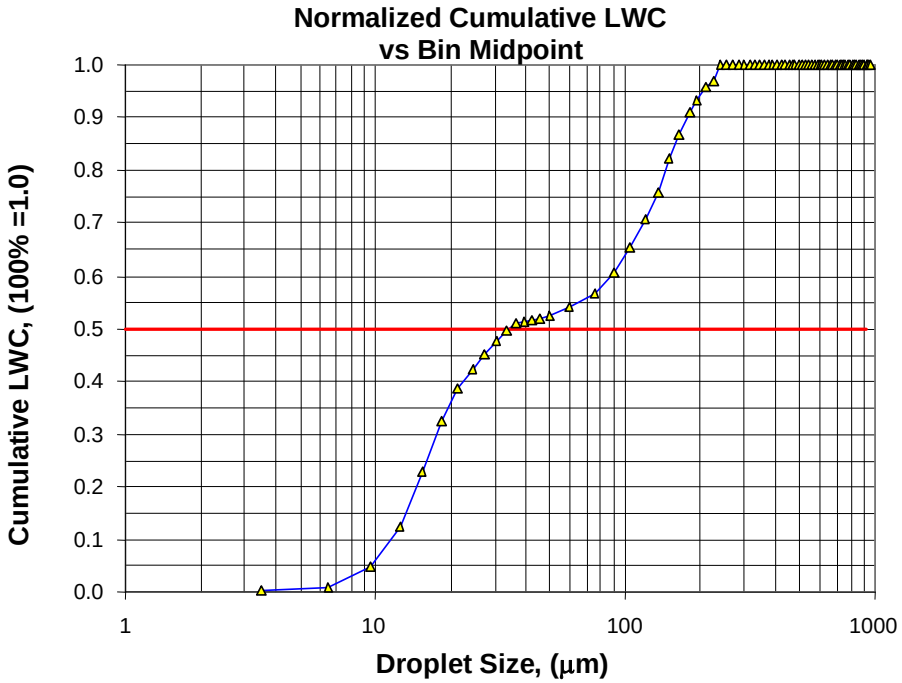


LWC histogram for Twin-Otter flight

SLD Icing Characteristics

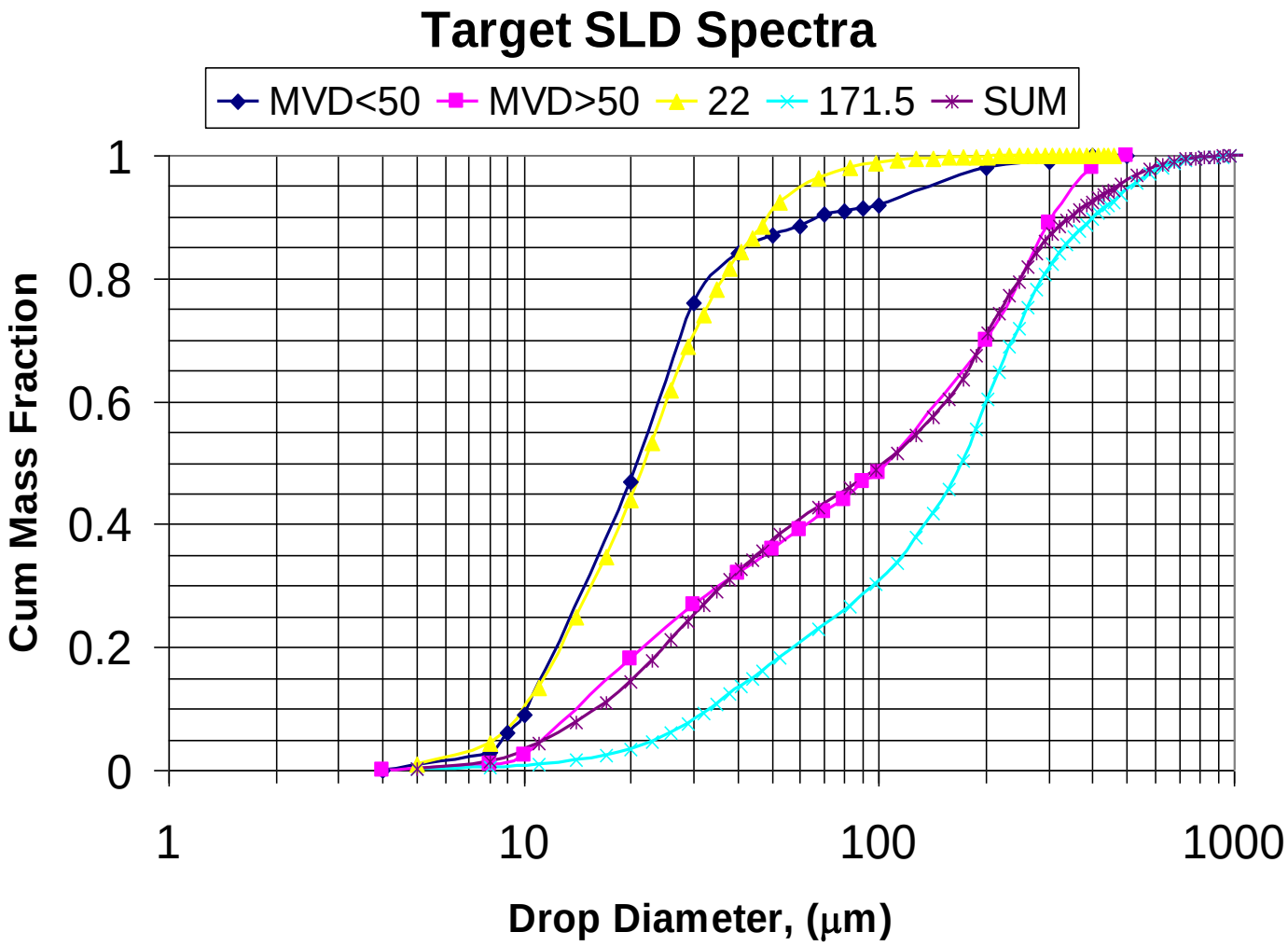


Cumulative percent LWC droplet distributions for MVD values of 15, 20, 30, and 40 microns in the NASA IRT.



Cumulative liquid water content as a function of droplet size in an SLD cloud

Simulation of a Bimodal Distribution in the IRT



SLD Icing Characteristics

SLD droplet temperature in an icing tunnel

- ✓ Icing tunnel spray system water supply temperatures are usually significantly above freezing to prevent freezing in the line and/or flash freezing of droplets emerging from the nozzles
- ✓ Heat and mass transfer from droplets to the airstream is the mechanism for super-cooling of the droplets in the cloud
- ✓ Larger droplets in SLD cloud require longer transit time from spray system to test section for super-cooling to ambient condition than standard spray cloud
- ✓ Most icing tunnels are designed to allow cooling to ambient conditions of smaller MVD spray cloud
- ✓ Measurements of droplet temperatures in a spray cloud are not simple to perform

Thus it is not clear whether existing facilities can produce SLD clouds with droplets at ambient temperatures

Experimental SLD Ice Accretion Simulation

Goal of this task

- ✓ Develop a list of known icing facilities
- ✓ Make list available to the public
- ✓ Identify range of capabilities for each facility when information is publicly available
- ✓ Survey facility owners to determine SLD capabilities
  - ➢ Droplet size range
  - ➢ Droplet size distribution in SLD conditions
  - ➢ Droplet temperature at test section if known
- ✓ Determine the gap in capabilities for SLD simulation
- ✓ Develop recommendations for desired characteristics of hypothetical SLD icing facility

Experimental SLD Ice Accretion Simulation

Status of this task

Task element	Status
Develop a list of known icing facilities	Completed
Make list available to the public	Submitted request for use of AIRA web site to host information
Identify range of capabilities for each facility when information is publicly available	Requesting information from facility contacts
Survey facility owners to determine SLD capabilities	Survey created and sent to facility contacts
Determine the gap in capabilities for SLD simulation	To be done when survey information is returned
Develop recommendations for desired characteristics of hypothetical SLD icing facility	To be completed for end of September